

***Rafflesia aurantia* (Rafflesiaceae): A New Species from Northern Luzon, Philippines**

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Abstract

A new Philippine species of *Rafflesia* from the Sierra Madre Mountain Range of northeastern Luzon is described. *Rafflesia aurantia* is the ninth presumed endemic species thus far described from the Philippines, and the fifth reported from the island of Luzon. This species is apparently allied to *R. tengku-adlinii* of Sabah - both are small-sized and their overall color is similar. Biogeographical considerations and the morphological differences between our new species and *R. tengku-adlinii*, however, strongly support the recognition of two distinct evolutionary lineages/species. The conservation status of the fast disappearing lowland dipterocarp forests in northeastern Luzon, particularly the type locality in the Quirino Protected Landscape (QPL) is also discussed and suggests that the new species may be highly threatened.

Introduction

The Philippines is fast emerging as the global center of *Rafflesia* diversity relative to its land area with the recent description of five more new species after the publication of *R. speciosa* Barcelona & Fernando (2002) from Antique Province in Panay Island. These newly described species are, *R. mira* Fernando & Ong (= *R. magnifica* Madulid, Tandang & Agoo), from Compostela Valley Province in Mindanao reported in 2005, *R. balettei* Barcelona & Cajano from Camarines Sur Province in Luzon (Barcelona *et al.*, 2006), *R. lobata* Galang & Madulid (2006) from the Central Panay

Mountains, and *R. leonardi* Barcelona & Pelser from Cagayan Province in Luzon (Barcelona *et al.*, 2008).

The recent rediscoveries of *R. manillana* Teschem. (Madulid and Agoo, 2008; Madulid *et al.*, 2008) and *R. philippensis* Blanco [as *R. banahawensis* Madulid, Villariba-Tolentino & Agoo (2007) and as *R. banahaw* Barcelona, Pelser & Cajano (2007; see also Barcelona *et al.*, 2009)] in their type localities as well as new populations of the presumed extinct *R. schadenbergiana* in Mindanao (Lays, 2006; Barcelona *et al.* 2008a, 2009) has tremendously increased our knowledge of the diversity and geographic distribution of this enigmatic plant group. A summary of our current knowledge on Philippine *Rafflesia* including their taxonomy, ecology, geographical distribution, and conservation status is detailed in Barcelona *et al.* (2009).

In 2004, a biodiversity survey that we conducted in the lowland forests of the western edge of the central portion of the Sierra Madre Mountain Range in northeastern Luzon, now designated as the Quirino Protected Landscape (QPL) in Quirino Province, resulted in the discovery of yet another population of *Rafflesia*. Comparison with currently known Philippine *Rafflesia* species and with that of the morphologically similar *R. tengku-adlinii* of Borneo strongly supports the recognition of a new species from Luzon, which we describe below.

Rafflesia aurantia Barcelona, Co & Balete, *sp. nov.*

Rafflesiae tengku-adlinii Mat-Salleh & Latiff (*ex Sabah*) *colori aurantae perigonii propemodum mentiens, sed ab ea sufficienter differt processibus disci centralis florum marium polymorphis et varie ramosis complanatis dispositis horizontaliter, processibus florum feminarum confertis complanatis dispositis verticaliter, ramentis longioribus (7-10 mm longis) glabris varie ramosis apicibus capitatis nec clavatis, antheris insigniter paucioribus (12-14).*

– **Holotypus:** Philippines. Luzon, Quirino Province, Sierra Madre Mountain Range, Quirino Protected Landscape, Nagtipunan Municipality, Barangay Matmad, Sitio Mangitagud, 16° 03' 22.5" N, 121° 28' 39.7" E, ca 450 m, disturbed lowland dipterocarp forest, ca 5 m away from embankment of boulder-strewn creek, 11 Jun 2004, *Bartolome & Balete 2543* (PNH, spirit collection, one male and one female flowers; isotypes, US, PUH, SING, two dissected mature buds and four immature buds in different stages of development). **Figs. 1-3.**

Mature **flower** buds 8.5-9 cm in diameter covered with atrocastaneous bracts; cupule of mature flowers light brown, 2.2 cm tall, 6.3 mm wide. Open flower ca 20 cm in diameter when fresh. **Perigone** lobes orange, 4.5-5.5 cm long, 6.3-7.7 cm wide, distantly disposed, outer surface uniformly covered with fine

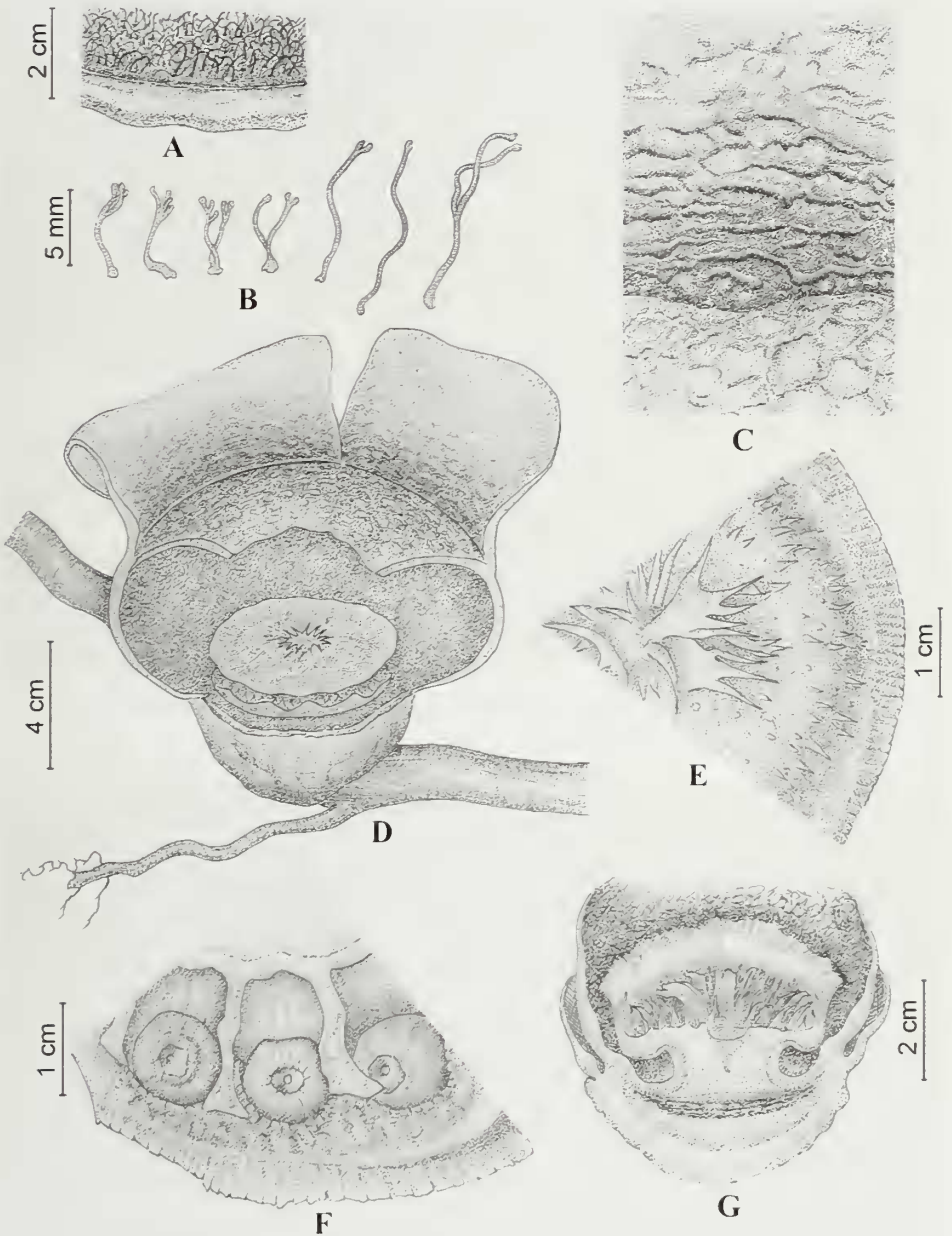


Figure 1. *Rafflesia aurantia*. A. Lanate ramenta en masse; B. Variably-sized and branched ramenta; C. Magnified outer surface of diaphragm and perigone lobe showing ridged, areoles-forming ornamentations; D. Partially-open male flower; E. Male flower disk showing polymorphic processes with central ones vertically-flattened and horizontally oriented; F. Semi-globular anthers embedded in deep sulci; G. Longitudinal section of a female flower showing lunate ovary and dense, vertically-oriented, and laterally-flattened processes.



Figure 2. *Rafflesia aurantia*, a fully expanded flower next to a senescent one (Photo: Danilo S. Balete).



Figure 3. *Rafflesia aurantia*, an early senescent flower next to a developing bud (Photo: Danilo S. Balete).

warts that are of sharp-edged, areoles-forming ornamentations when fresh, these turning into blunt ridges in alcohol-preserved specimens. **Diaphragm** concolorous and similarly ornamented as perigone lobes (except along the aperture rim), pentangular, *ca* 10 cm across; windows absent; aperture 3-3.6 cm in diameter. Lower surface of diaphragm (except along the aperture margin) covered with uniformly lanate, glabrous ramenta, that are rather sparse towards the aperture, becoming dense towards the base of the floral cavity, 7-10 mm long, slender, unbranched to furcate, entirely glabrous, tips swollen. Disk 5.5-6 cm across, *ca* 6 mm thick; neck of column *ca* 3 cm tall. Disk processes flattened, polymorphic, centrally disposed ones 5-10 mm long, variably branched, horizontally-oriented in the male flowers, dense, flattened, and vertically-oriented in the **female flower**, peripheral ones much smaller, 0.5-2 mm long, narrowly lanceolate, spinose, or markedly reduced into tubercles, tips tufted with golden brown hairs. Anthers of **male flowers** 12-14, semi-globular, each hidden in a deep sulcus; anther pores *ca* 2.5 mm across. Ovary of female flowers lunate, *ca* 3.5 mm long, *ca* 6.5 mm wide (fig. 1A-G).

Etymology: This species is named after the orange coloration of the flowers.

Ecology: Plants of *R. aurantia* have all been found parasitic on prostrate stems and underground roots of the host liana, *Tetrastigma* (which unfortunately was not collected) and has never been found yet to grow on the climbing stems of the host. Some murid rodents that may possibly be the seed dispersers of *Rafflesia* recorded on-site include *Apomys*, *Bullimus*, and *Rattus everettii*, whereas flower visitors observed were metallic bottle flies.

Distribution and habitat: So far known only from the type locality. The population was concentrated in disturbed lowland dipterocarp forest along the lower slopes of Mungiao Mountains, in the vicinity of the headwaters of Cagayan River, northeastern Luzon's principal drainage system and the Philippines' longest river. With a prevailing canopy of 20-25 m and occasional emergents to *ca* 40 m in height, this forest is dominated by *Shorea* spp. and *Anisoptera thurifera* (Dipterocarpaceae). Several species of *Lithocarpus* (Fagaceae), *Syzygium* (Myrtaceae), *Litsea*, and *Cinnamomum* (Lauraceae) dominate the subcanopy layer. Open grasslands and agricultural areas are located merely half a kilometer away.

Conservation status: Though observed to be common locally, this new species is thus far known only from a single population. The sporadic collections of plant specimens by R.C. McGregor in 1912 at nearby Dupax to the north, and Ramos and Edaña in 1925 at Mt Alzapan to the east, are

the only historical botanical records notable in this part of Luzon. Small-scale logging for certain premium timber species as well as forest clearings for swidden agriculture are rather prevalent in the area. However, it is the commercial open-pit mining (chiefly for gold and copper) that poses the gravest threat for this *Rafflesia* habitat. Despite the establishment of an approximately 206,875 ha new protected area, the Quirino Protected Landscape (Presidential Decree No. 548 dated 9 February 2003), about 30,930 ha of these were recently excised in favor of mining, resulting in the fragmentation of QPL into three parcels.

Taxonomic and biogeographical notes: *Rafflesia aurantia* closely resembles *R. tengku-adlinii* of Borneo in size, flower color, habit, and the absence of windows. It is, however, different from the latter by its lanate, entirely glabrous, and substantially longer (7-10 mm, longest in the genus) ramenta that are sparse towards the diaphragm and absent near the aperture rim, its polymorphic, flattened, irregularly and sometimes horizontally disposed, and multi-branched processes, and fewer anthers (12-14). In *R. tengku-adlinii*, the ramenta extend to the diaphragm (in fact, they are visible near the diaphragm aperture), are significantly shorter (3-5 mm), and covered with fine bristles. Ramenta characters, such as disposition, morphology, and length, show little variation within species and are therefore useful characters for distinguishing species of *Rafflesia* (Nais, 2001:18-19; Mat Salleh, 1991:10). In addition to being different in characters of the ramenta, *R. aurantia* is also distinguished from *R. tengku-adlinii* by disk process morphology. The processes of *R. tengku-adlinii* are much reduced relative to those of *R. aurantia* and they are more or less solitary and regular in disposition. Furthermore, *R. tengku-adlinii* has more anthers than *R. aurantia* (20 in the holotype of the former, the only specimen described and measured in the protologue). Determining the anther number in most species of *Rafflesia* (except those in *R. manillana* and *R. lobata* where the wide diaphragm aperture exposes the anther impressions on the floor of the floral tube) is destructive in nature. Perhaps because of its rarity, only the holotype of *R. tengku-adlinii* was measured and described in detail. In addition, the fine, sharp-edged, areoles-forming ornamentations (warts?) on the outer surface of the perigone lobes and diaphragm in fresh flowers of *R. aurantia* are different from the quite distinctive pustular warts on the perigone lobes of fresh flowers of *R. tengku-adlinii*. In addition, the geographic distributions of *R. tengku-adlinii* (Sabah, Borneo) and *R. aurantia* (northern Luzon), coupled with the generally low dispersal ability of *Rafflesia* do not strongly support gene flow between these disjunct populations to occur. The short anthesis, pollen germinability and longevity (Nais and Wilcock in Nais 2001: 58), the low seed viability (Nais and Wilcock, 1999 in Nais 2001: 78-80), and the obligate parasitic nature of

Rafflesia make gene flow unlikely, although long distance dispersal events in the past cannot be discounted. We therefore presume that both populations are reproductively isolated. Although Luzon may have been connected to Northern Borneo and Sabah via the Sulu-Cagayan Arc before the Miocene, i.e. ca. 50 million years (MY) ago (Hall, 2002: 381), there is no evidence of the existence of *Rafflesia* (or its immediate ancestor) during this time. The age of the stem-lineage of Rafflesiaceae was estimated by Davis *et al.* (2007) to be 46 MY old, whereas the age of the crown group/genus *Rafflesia* was estimated by Barkman *et al.* (2008) to be 12MY old, with most species divergences having occurred within the last 1-2 MY. Hence, the scenario that both Borneo and Northern Luzon populations may represent relicts of a more widely distributed species (vicariance) in the past is unlikely.

Some *Rafflesia* species, (e.g., *R. arnoldii* in Peninsular Malaysia, Borneo, & Indonesia and *R. speciosa* in Panay & Negros Islands) do defy transoceanic barriers. However, these islands were historically connected during the Pleistocene when the sea level was much lower than today and, in the case of Panay and Negros, represent land bridge islands that, together, form a single Pleistocene aggregate island complex sharing many endemic fauna (Wikramanayake *et al.*, 2002).

Thus, both *R. tengku-adlinii* and *R. aurantia* are likely examples of morphologically semi-cryptic species, and possibly, an example of extreme convergence in distantly related lineages. Studies on the accelerated rates of floral evolution using molecular markers in 15 species (out of the 26 currently recognized species) of *Rafflesia* by Barkman *et al.* (2008) reveals that genetic affinity is closer among those species found in the same geographic region than those that are morphologically similar but found in different geographic regions. Likewise, preliminary maximum likelihood analyses of both nuclear and mitochondrial markers of five species of Philippine *Rafflesia* (*R. manillana*, *R. leonardi*, *R. schadenbergiana*, *R. speciosa*, and *R. lobata*) and *Rafflesia* species from Peninsular Malaysia and Borneo have recovered the Philippine species as a monophyletic clade sister to all the other species of *Rafflesia* (B. van Ee, pers. comm.).

Biodiversity in Luzon's Sierra Madre Mountain Range

The Sierra Madre Mountain Range constitutes the largest block of lowland forest remaining anywhere in the Philippines. It also boasts one of the country's richest bird fauna, including some of the most rare and threatened, such as the Philippine Eagle (*Pithecophaga jefferyi*) and the Isabella Oriole (*Oriolus isabellae*) (Danielsen *et al.*, 1992; Mallari *et al.*, 2002). Mammal diversity is also remarkably high and recent surveys strongly suggest that the Sierra Madre is a unique center of mammal endemism (Danielsen *et al.*,

1992; Rickart *et al.*, 1998; Heaney, pers. comm.). Herpetological diversity in the Sierra Madre appears similarly high, and distinct from that of the Cordillera Central, southern Luzon, or the Bicol Peninsula (Brown *et al.*, 2000; Diesmos *et al.*, 2005; Diesmos and Brown, unpublished data).

Many Philippine endemic plants are also found to occur in the Sierra Madre mountain range, most notable of which is *Podosorus angustatus* Holttum, a monotypic endemic fern genus known only from the type. At the 16-ha Palanan Forest Dynamics Plot, one of the large-scale forest plots coordinated by the Smithsonian Center for Tropical Forest Science (CTFS) and Arnold Arboretum of Harvard University, 142 out of 323 tree species recorded are Philippine endemics (Co *et al.*, 2006), with 5 species thought to be possibly new to science.

The discovery of *Rafflesia* in the Sierra Madre Mountain Range and on other similar lowland habitats in the Philippines highlights the importance of this fast disappearing forest type in the conservation of the country's threatened biodiversity (Tan *et al.*, 1986).

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